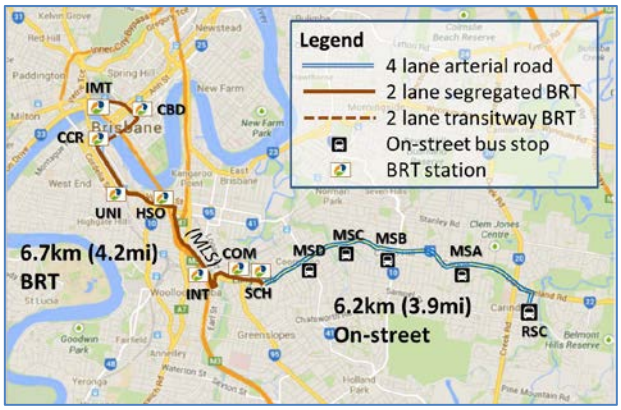
Stochastic Analysis of Transit Route Segments' Passenger Load Variation for Capacity & Quality of Service Assessment

Introduction

- This study uses weekday Automatic Fare Collection (AFC) data on a premium bus line in Brisbane, Australia
- Stochastic analysis is compared to peak hour factor (PHF) analysis for insight into passenger loading variability
- Hourly design load factor (e.g. 88th percentile) is found to be a useful method of modeling a segment's passenger demand time-history across a study weekday, for capacity and QoS assessment
- Hourly coefficient of variation of load factor is found to be a useful QoS and operational assessment measure, particularly through its relationship with hourly average load factor, and with design load factor
- An assessment table based on hourly coefficient of variation of load factor is developed from the case study



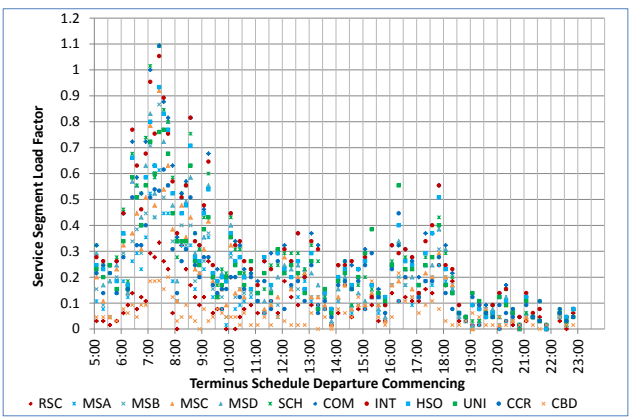
Measure	Inbound
Span	18h
Early frequency	15
a.m. peak frequency	**10**
Off-peak frequency	15
p.m. peak frequency	15
Evening frequency	15

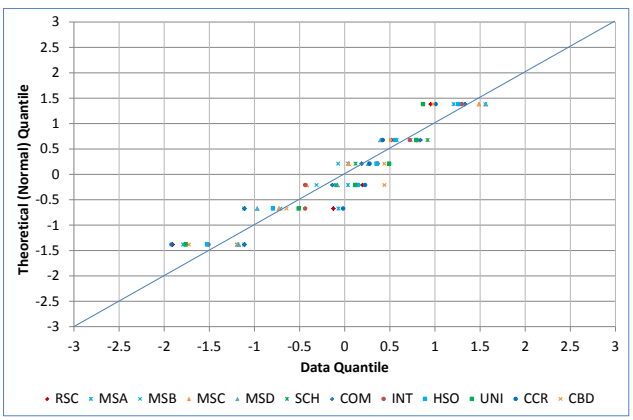
Inbound Segments' Passenger Load Factors' Profiles

- Strong morning peak due to CBD work trips
- Crush load conditions (MSL > 1) on 07:25 service across inner segments MSD – SCH – COM - INT
- Softer evening peak with contra-peak direction demand from regional shopping center, inner urban connections

Quantile – Quantile Tests for Normality of Segments' Hourly Load Factor Distributions

- Small sample sizes due to limited frequencies makes other normality testing difficult
- Line of equality comparison for morning peak hour strongly indicates normality
- No evidence of systematic bias particularly for most extreme quantiles
- Methodology does not use extreme tails so truncated normal distribution not necessary





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Segment *i* Peak Hour Factor During Study Hour *H*

$$PHF_{i,H} = \begin{cases} \dfrac{\sum_{k=1}^{m} P_{k,i}}{m \max\limits_{1 \le k \le m} \left(P_{k,i}\right)}, & m < 4 \\ \dfrac{\sum_{k=1}^{m} P_{k,i}}{4 \max\left(\max\limits_{1 \le k \le m-1} \left(P_{k,i} + \dfrac{(m-4)}{4} P_{k+1,i} \right), \max\limits_{1 \le k \le m-1} \left(\dfrac{(m-4)}{4} P_{k,i} + P_{k+1,i} \right) \right)}, & 4 \le m \le 8 \end{cases}$$

- Number of services
- Passengers on board each service

Load Factor of PHF Service Traversing Segment *i* During Study Hour *H*

$$LF_{PHF,i,H} = \frac{\sum_{k=1}^{m} \left(\dfrac{P_{k,i}}{P_{MSL,k}} \right)}{m \, PHF_{i,H}}$$

- Number of services
- Passengers on board each service
- Maximum Schedule Load of each service

Normal Distribution Percentile of Load Factor of PHF Service Traversing Segment *i* During Study Hour *H*

$$F\left(LF_{PHF,i,H}\right) = \Phi\left(\frac{LF_{PHF,i,H} - LF_{av,i,H}}{LF_{sd,i,H}} \right)$$

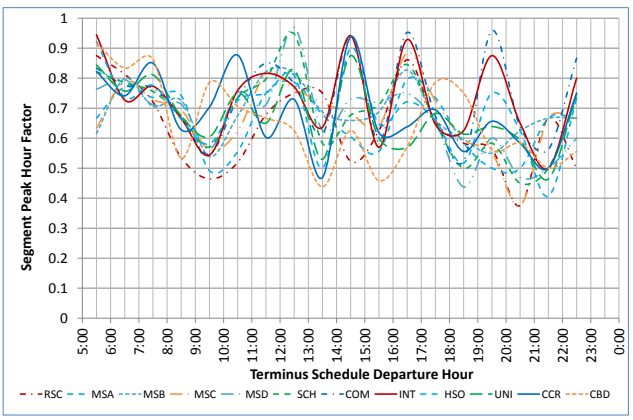
- Average load factor across all *m* services
- Standard deviation of load factor over all *m* services

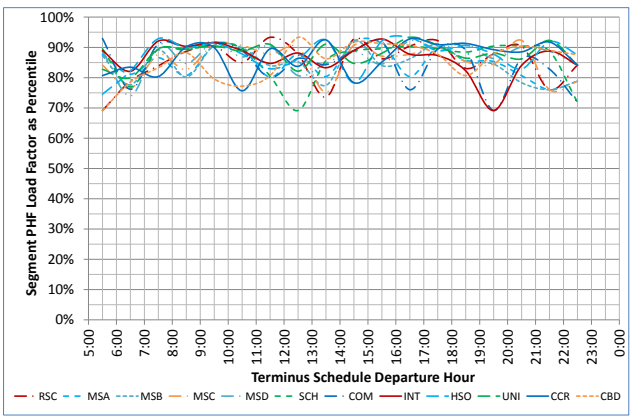
Segments' PHF Time Histories (Clockface Hour)

- PHF correlates somewhat between consecutive segments
- Some irregular oscillation throughout day
- Low PHFs mainly during off-peak times when 15min frequencies can easily skew downward
- PHF important so operator can ensure highest contiguous 15 minutes of hour can be accommodated / managed
- PHF similar to a 15min peak's average load – which may be used as a passenger load QoS standard

Segments' PHF Load Factors Time Histories as Percentiles

- PHF load factor varies irregularly between 75th and 95th percentiles across all segments
- Highlights conceptual difference between PHF and Hourly Design Percentile
- Hourly Design Percentile sensitive to both hourly average load factor and standard deviation of load factor





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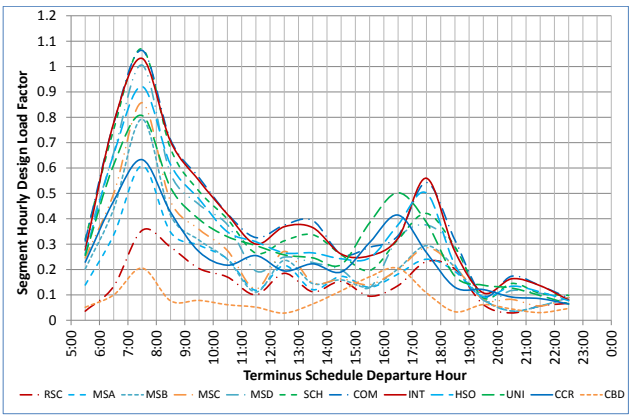
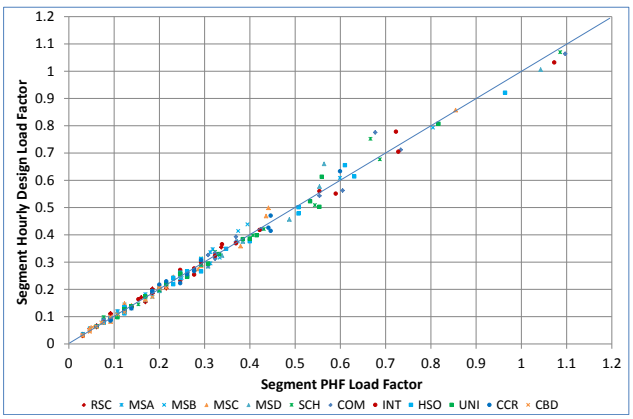
Segments' Hourly Design Load Factor

- 88th percentile corresponds to 7th highest minute of hour – appropriate design state
- Each segment's design profile envelops most of its load factors by service

Segments' PHF Load Factor vs Hourly Design Load Factor

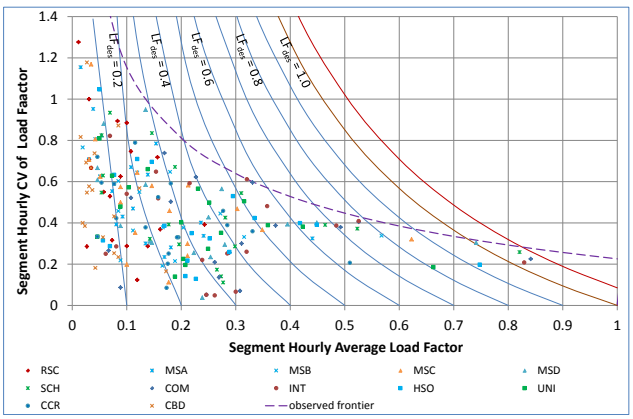
- Line of equality comparison shows very strong correlation ($R^2 = 0.98$)
- No systematic bias evident





Segment Hourly Coefficient of Variation of Load Factor for Capacity and QoS Assessment

- Data points on right side are most highly loaded segments during morning peak
- Data points on left side vary substantially
- Low CV means uniform loading, dispersed boarding demands, good schedule maintenance
- Form of chart shows strong potential in fingerprinting route's utilization and QoS



Hourly CV Load Factor	Hourly Average Load Factor ≤ 0.5	Hourly Average Load Factor > 0.5
0.0 to 0.1	very even passenger demand	possible pass-ups under high load
0.1 to 0.2	relatively even demand	relatively even passenger demand
0.2 to 0.3	some uneven demand / minor bus bunching	some uneven demand / some bus bunching
0.3 to 0.4	relatively uneven demand / some bunching	uneven demand / considerable bunching
0.4 to 0.6	uneven demand / considerable bunching	uneven demand / considerable bunching
0.6 to 0.8	very uneven demand / bunching	unlikely
0.8 to 1.0	very uneven demand / bunching	not possible
1.0 to 1.2	highly uneven demand / bunching	not possible
1.2 to 1.4	extremely uneven demand / bunching	not possible

Advantages of Methodology

- Requires only AFC data
- Can be used to identify along a route, in time and space, operational concerns such as pass-ups, bunching

Future Research

- Pursue application of stochastic approach to transit route across a number of consecutive study days
- To gain stronger insight into influences of day-of-week, seasonality, weather conditions on reliability